vehicle faults; engine; turbocharger; technical conditions

Jan FILIPCZYK
Silesian University of Technology, Faculty of Transport
Krasińskiego 8, 40-019 Katowice, Poland
Corresponding author. E-mail: jan.filipczyk@polsl.pl

CAUSES OF AUTOMOTIVE TURBOCHARGER FAULTS

Summary. This paper presents the results of examinations of turbocharger damages. The analysis of the causes of faults in 100 engines with turbochargers of cars, buses and trucks has been carried out. The incidence and structure of turbocharged engine faults has been compared to the causes of faults of naturally aspirated engines. The cause of damage, the possibility of early detection, the time between overhaul and the impact on engine operation for each case of fault was carried out as well. The results of examinations allowed to determine the most common causes of damages and how to prevent them.

PRZYCZYNY USZKODZEŃ TURBOSPRĘŻAREK W SAMOCHODACH

Streszczenie. W artykule przedstawiono wyniki badań uszkodzeń turbosprężarek. Przeanalizowano przyczyny uszkodzeń 100 turbosprężarek silników samochodów osobowych, autobusów oraz samochodów ciężarowych. Porównano częstotliwość występowania uszkodzeń silników z turbosprężarkami z uszkodzeniami silników wolnossących. Dla poszczególnych przypadków określono przyczynę uszkodzenia, możliwość jego wczesnego wykrycia, resurs eksploatacyjny oraz wpływ na pracę silnika. Przeprowadzone badania pozwoliły na określenie najczęstszych przyczyn uszkodzeń oraz sposobów zapobiegania im.

1. INTRODUCTION

During the last years, most research worldwide has been concentrated on the reduction of engine fuel consumption. Downsizing and supercharging is one of the most promising approaches to reduce the fuel consumption. The challenge of downsizing is to reduce the engine displacement while keeping the same performance in terms of torque and power, initially as a large engine and to ensure the improvement of engine's efficiency. The use of turbochargers for automotive engines is currently considered as one of the most promising ways to improve fuel economy with an acceptable cost-to-benefit ratio. Turbocharging is the subject of extensive research, which seeks to overcome its drawbacks, such as low-end torque, turbo-lag and compressor surge.

The turbocharger is a device of a relatively simple construction. However, the precision of putting the parts together and very difficult working conditions such as high rotation speed, high temperature influence the occurrence of serious damages. The damages of turbocharger and its control system usually result in a wrong performance or completely blocking of the engine. Considering the high cost of repairs it is essential to prevent faults of turbochargers through the use of appropriate technical services and modern methods of diagnosis. The use of continuous monitoring of turbocharger operating parameters is not possible due to the small size of automotive turbochargers, high rotor speed, above 100.000 rpm, high operating temperatures, etc. The published results of scientific investigation concern diagnostic methods for turbochargers which are used in big stationary engines and in locomotive and marine applications [1, 2].

The investigation focuses on the use of acoustic signals as the diagnostic information. In many research centers, research works are conducted regarding the problem of ensuring appropriate lubrication, rotordynamics, baring design and the reduction of friction losses [3-10]. Similar problems have occurred in other engines, such as maritime transport [11].

The results of investigations concerning the most common causes of turbocharger faults and the impact of turbocharger damages on the engine performance have been presented in this paper.

2. METHODS OF EXAMINATIONS

The faults of turbochargers were the main goal of engine examinations. The investigations have been conducted in authorized service stations. The investigations have been carried out in two stages. The engines with turbochargers in cars, buses and trucks have been examined. The first stage concerned the analysis of 100 cases of damage turbochargers. The value of overhaul lifetime and the impact of faults on technical state of the engine have been determined for each case of turbocharger damage. The diagnostics of engine using OBD system has been carried out where it was possible. The structure of turbocharger types which was examined has been presented in Fig. 1.

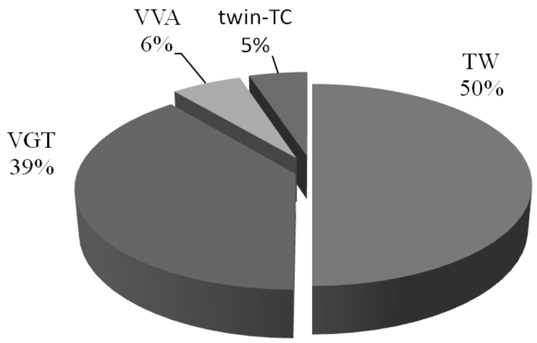

Fig. 1. Structure of turbocharger types TW – turbocharger with wastegate, VGT –with turbine with variable geometry, VVA – variable valve actuation, twin-TC – two turbochargers

Rys. 1. Struktura typów turbosprężarek TW – turbosprężarka z zaworem obejściowym, VTG – turbina o zmiennej geometrii, VVA – turbosprężarka z zaworem sterującym

The structure of vehicle faults was the aim of the second stage of investigations. In the second stage 4700 vehicles have been examined. The structure of the type and age of the tested vehicles has been presented in Table 1.

Table 1

Type and age structure of tested vehicles

Vehicle category	Percentage of vehicles in age group					Total number of vehicles
	2 – 3 years	4 – 5 years	6 – 7 years	8 – 9 years	10 years and more	
M1	8%	8%	30%	42%	12%	4000
M3	20%	10%	10%	10%	50%	200
N1	20%	30%	20%	10%	20%	250
N2				50%	50%	20
N3	20%	30%	20%	20%	10%	230

The results concerning the structure of engine failure were compared to the results of investigation which had been presented in previous papers (Fig. 2) [12, 13]. The results of comparison between the fault structure of turbocharged engines and naturally aspirated engines have been presented in Fig. 3.

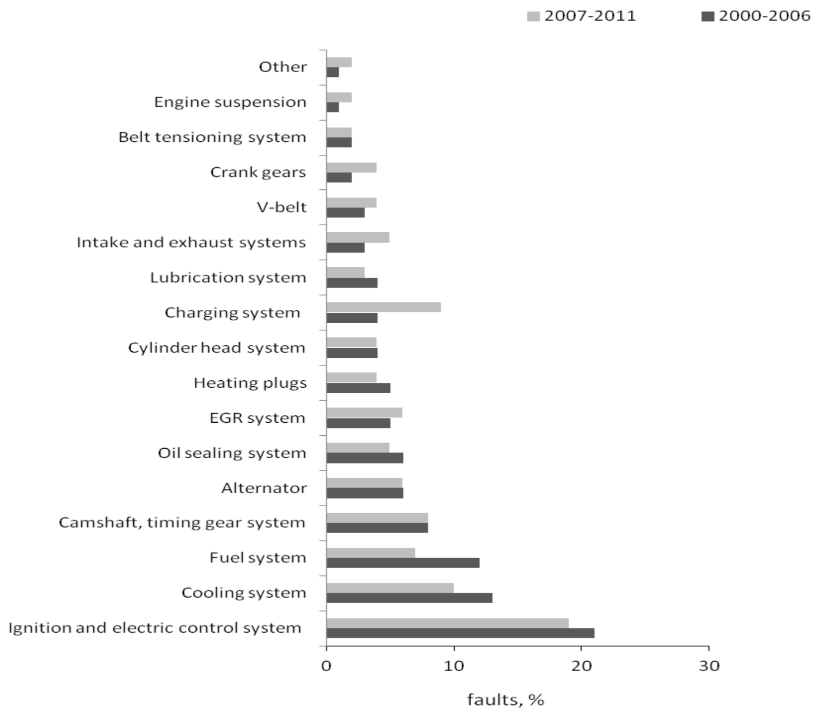

Fig. 2. Structure of engine faults – results of investigations which were carried out in 2000 – 2006 and 2007 – 2011
Rys. 2. Struktura uszkodzeń silnika – rezultaty badań prowadzonych w latach 2000 – 2006 i 2007 – 2011

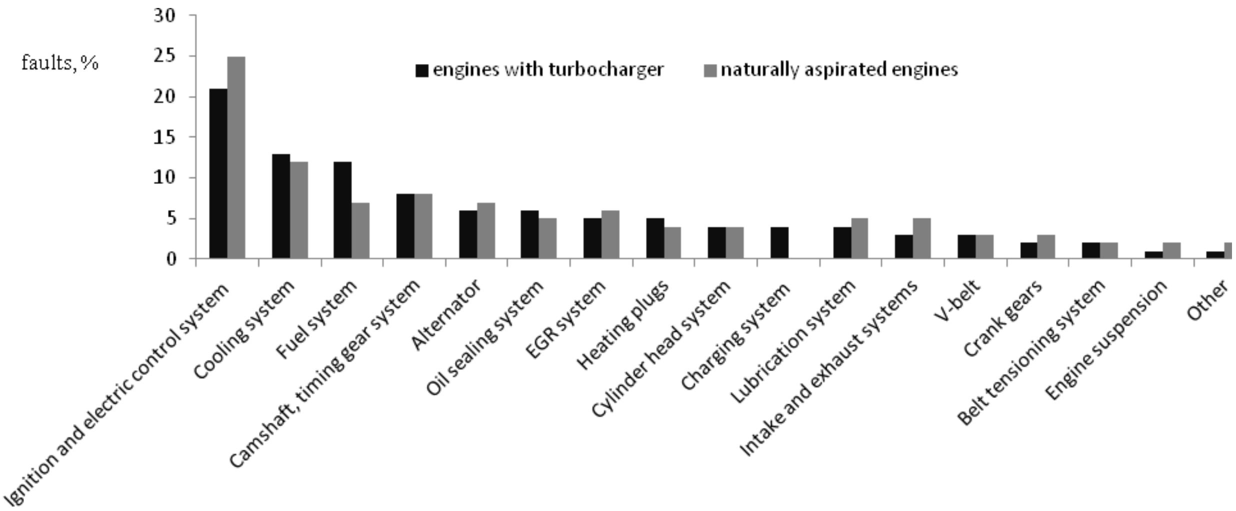

Fig. 3. Structure of turbocharged and naturally aspirated engine faults
Rys. 3. Struktura uszkodzeń silników z turbodoładowaniem i wolnossących

3. EXEMINATION RESULTS

The types of faults of engines which were connected with turbocharging system can be classified as follows – low power of engine, oil leakage, abnormal turbocharger noise, damages of wastegates, damages of pneumatic control system in VGT turbochargers and electrical control system in VGT turbochargers, faults of engine control module and mechanical damages of turbine and compressor. The structure of faults has been presented in Fig. 4.

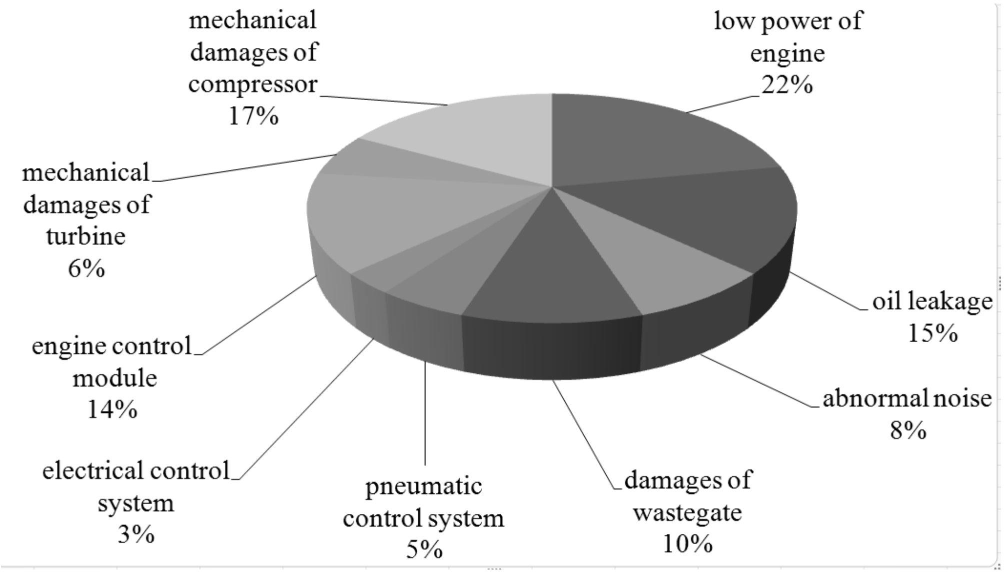

Fig. 4. Structure of engine faults connected with turbocharger
Rys. 4. Struktura uszkodzeń silnika związanych z turbosprężarką

The causes of turbocharger faults can be classified as oil starvation, oil contamination, foreign object damage, overheating, normal wear and tear. The structure of the causes of turbocharger faults has been presented in Fig. 5.

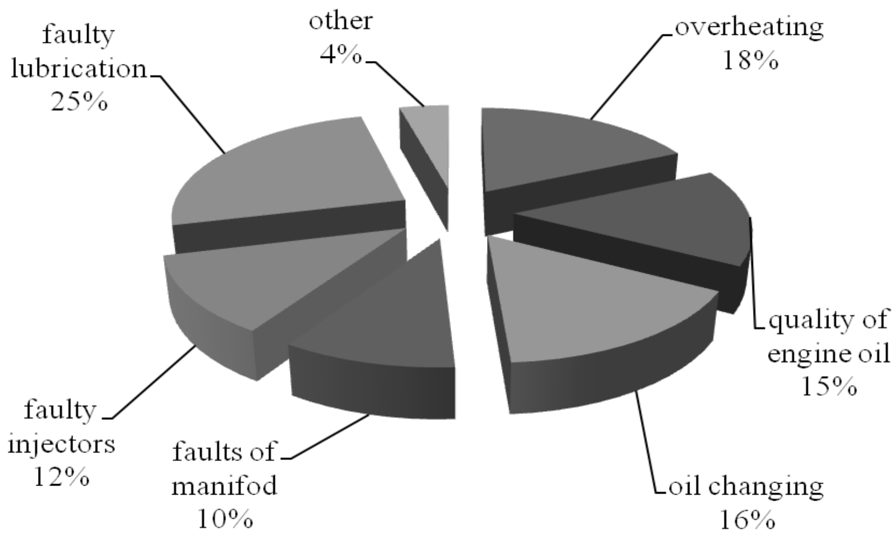

Fig. 5. Structure of causes of turbocharger faults
Rys. 5. Struktura przyczyn uszkodzeń turbosprężarek

The causes of damages due to overheating include blocked air filter, shutting off the engine after work at high or medium load too soon, poor quality of engine oil, too long time between oil changing, not airtight inlet and exhaust manifold which are not airtight, faulty injectors, faulty lubrication system of the turbocharger, defective drainage oil system (crankcase ventilation defects).

The causes of damages from exceeding the rotation speed limit include increasing the engine power by changing the control parameters and overloading the turbocharger.

The main symptoms of turbocharger damages include poor co-operation between the charging system and the engine control unit system, too low boost pressure at low engine speeds and significant deterioration in its performance as well as increase of toxic exhaust emissions, incorrect fuel mixture, the combustion temperature increase, which can damage the turbocharger and the engine, too high boost pressure which results in exceeding the rotation speed of a turbine and the risk of mechanical damage (cracks) of a rotor, fast (in extreme cases sudden) increase of boost pressure, which can damage piston-crack system or engine timing system, noisy work of turbochargers, usually accompanied by the accelerated wear, considerably increased toxicity of exhaust gases, which eliminate the vehicle from being used.

Durability of the turbocharger can be defined as the ability to maintain the normative values of the significant operating properties (for example right boost pressure, vibration), during generalized operating time:

$$Tw(t) = \varphi[R(t), W(t), D(t)], \tag{1}$$

where: *R(t)* – reliability of the turbocharger as a random event of reaching the boundary state by particular components, *W(t)* – forcing spectrum of physical aging, *D(t)* – resistance of turbocharger elements to thermal and mechanical forcing.

Increasing the mechanical and thermal forcing *D(t)* reduces the durability *Tw(t)* of turbocharging systems. Obtaining the required level of durability is possible by using turbocharger components made of materials with significantly increased resistance to mechanical and thermal load.

The reliability *R(t)* of turbocharger is related to the design and the production quality, operating conditions (e.g. oil condition, oil supply) and system of technical service. The results of examination of faulty turbochargers have shown that fifty six percent of faults were connected with engine lubrication system. Twenty five percent of faults were connected with engine lubrication system. The results of previous studies [12, 13] have shown that the turbocharged engines were much more susceptible to malfunction of lubrication system, compared to naturally aspirated engines. Possibility of turbocharger damages as a results of faults, which had been connected with engine lubrication system increased according to mileage of the car. This has been due to operational reasons, such as wear of lubrication system components, insufficient oil pressure, but also poor service quality of older cars. The main causes of turbocharger faults during the initial period of operation (below eighty thousand kilometres) have been connected with turbocharger control system and improper operation

4. CONCLUSIONS

Faults of turbocharger affect engine durability because of a significant increase of the application of turbocharger systems for engines and the increase of engine load. The causes of turbocharger damages can be described as operational circumstances, manufacture errors, maladjustment of the engine type for given purposes, a mismatch between the turbocharger to the engine.

A significant increase in the number of damages of engines with turbochargers (Fig. 2) has been connected probably with more frequent application intricate charger systems and wrong choice of materials used for the production of the components of turbochargers. Reducing dimensions of turbochargers allows to achieve much higher rotation speed of turbocharger rotor, but it affects the increase of the susceptibility to damages caused by improper lubrication and mistakes made during the service. The operational circumstances are related to the operational errors, not following the service rules and errors during a turbocharger replacement.

Engines with turbochargers are more sensitive to operating conditions, especially in transient states, oil quality as well as oil pressure. A high percentage of faulty engines with low mileage shows that early diagnosis of incorrect operation of turbochargers is extremely important. The faults of electronic control system and engine management malfunction may be the reason of a complete destruction of the turbocharger. The commonly used methods of diagnosis may not be sufficient do detect certain types of failures in the initial stage. The development of diagnostic methods of engines is much slower than the progress in a turbocharger systems design.

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